AUTONOMOUS UNDERWATER VEHICLE SYSTEMS

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LONG TERM GOALS

To understand the physical and biological relationships often requires high resolution sampling far exceeding present capabilities. If spatially adaptive sampling can be developed, data resolution can be greatly improved over that presently possible with conventional sensor platforms. One technique to achieve both spatially and temporally adaptive sampling is an Autonomous Oceanographic Sampling Network (AOSN). The purpose of the network is to provide a technique for spatially adaptive sampling capable of resolving evolving gradients with sparsely distributed sensors. Each network consists of a base buoy and a number of Autonomous Underwater Vehicles (AUVs) at fixed levels. The base buoy serves as a navigation beacon, energy source, telemetry link and surface sensor platform. Each AUV functions as a subsurface sensor platform, short term data logger and programmable, navigable vessel. The long term goal is to develop a suitable AUV to operate in the AOSN.

OBJECTIVES

The current objective is to define, construct and test a robust and practical integrated system for homing into an omni-directional dock, as well as the dock itself. After proof of concept of the system, extensive testing was to be undertaken to validate the design and define the range of parameters for which the homing and dock were operational.

In order to minimize vehicle development time and cost, and to have a common platform for testing the various AOSN sub-systems, a single vehicle was chosen. This is the Odyssey AUV developed at MIT. The NC Consortium (NCC), consisting of a joint effort by NCSU (Yates Sorrell) and Electronic Design Consultants (EDC) with Mike Feezor directing the work at EDC, took delivery of an Odyssey in late August 95. This AUV has been fitted with the NCC electromagnetic homing system, and was used to evaluate this technique as the AOSN homing sub-system.

A second objective was the NCC group was the development of a suitable undersea interface between the dock and the AUV which is in the dock. One objective of the interface was to serve as a communication link between the dock and AUV. It was also desired that an integral part of the interface system would provide a link for power transfer from the dock to the AUV. This power transfer link is to be used to re-charge the batteries of the AUV. The communications and power transfer system was to be adapted to several dock/AUV configurations, and was to be ultimately tested in the deep ocean environment.

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APPROACH

There are a number of available technologies for underwater guidance including, optical, acoustic and electromagnetic (EM) systems. Optical systems provide good response in non-turbid environments, but may be limited over a wide range of background lighting and water turbidity conditions, Cowen, Briest and Dombrowski (1997). In addition, with an optical system, the optical sensors must have “line of sight” access before homing can be initiated. Acoustic systems are proven for position finding at distances to less than 1 meter, and under a wide variety of oceanographic conditions, Singh, Yoerger and Bowen (1997). However, sensing in real time the orientation of the AUV relative to a single dock entry angle is can become complex with acoustic homing. Moreover, successfully homing when the AUV is very close to the dock, requires precise spatial measurements with fairly rapid temporal resolution. It is in the last stage of docking, where the AUV is close to and approaching the dock, that is the most critical and difficult in the docking operation. For an acoustic system, this translates into a system with a high up-date rate, which often means the homing system must be dedicated to this operation. Finally, an acoustic system will have increased complexity if it must operate near the surface, bottom or other sources of reflected acoustic signals. Given the requirements of a dedicated system for near field homing, a precise (less than 20cm) position location near the dock, and the desirability of sensing not only the AUV bearing and distance to the dock, but also the orientation of the AUV relative to the entrance of the dock, an electromagnetic (EM) system was selected for the homing application.

The power and communications interface is via an inductive coupling, in which one part of the coupling or transformer is mounted on the AUV and the other part of the transformer is mounted on the dock. In operation, the dock portion of the coupling or transformer is mated with the AUV transformer and forms an inductive link or a transformer. When the AUV is to leave the dock, the two parts separate, and the coupling or interface is broken. There are three sets of winding, two are required for the Ethernet communications link and one for the power transfer link. The winding for the power link is on the tapered portion of the core. One of the Ethernet links is through a winding on the inner core, the other through a winding on the periphery of the core. Electrical connection to the three windings is via SeaCon connectors.

WORK COMPLETED

Work during the past year has been on testing and evaluation of the Electromagnetic (EM) homing system and on construction and testing of the power and communication interfaces or AUV/Dock interface. The present EM homing design was tested in Buzzards Bay in March 1996. At these field trials two other homing systems were also tested. These were and optical homing system developed by NRad and an acoustic system developed by WHOI. The EM homing system proved to be as, if not more consistent, in guiding the AUV into the dock at these trials. However, one limitation of this system was also exposed during these trials. This was the limited range of the EM system in salt water. Work the past year has been on improved EM homing system, largely by increasing the power and signal differentiation. There has also been improved integration of the homing signals into the Odyssey control system. Several schemes to improve the range have been considered. One technique is to use the field strength to estimate

AUV-to-dock distance, and then correcting the phase shift based on the conductivity of the sea water. An alternative to this would be to use two frequencies for the horizontal and vertical coils that are closer to each other. In that way the relative phase lag between the two signals would be less. However resources were not available to test either of these techniques.

Concurrent with the EM homing system the NCC also had the task of develop/construction and testing of the AUV/Dock interface. An inductive system has been developed with the power link in the core and an Ethernet communication link on the periphery of the power link This system has been designed to interface with the dock and the Odyssey AUV using standard connectors. A combination of power and communication wet amplifiers has also been constructed to operate with the inductive link. For preliminary testing, a high pressure wet chamber was constructed. This was for wet bench testing. The interface has undergone wet testing in a test chamber in NCC, and subsequent field testing in the winter 96-97. There was failures of some of the communication amplifiers, and the system was re-designed with different amplifiers and mounted techniques. The interface system was successfully tested on the MIT/WHOI Odyssey in the summer of 97.

RESULTS

Work for the last year has been primarily on the interface system. To date the system has been bench tested in both atmospheric and high pressure salt water. In addition to these bench tests, are a limited number of tests where the present power and communications interface was installed on the joint MIT/WHOI Odyssey. This system employed acoustic homing, with an onmi-directional dock. Thus the geometric configuration of the AUV/dock latch and the location of the interface transformer were different. These field tests are described by Bellingham (1997). However, the performance of the power and communications interface from both sets of tests are briefly given here.

The pressurized salt water bench tests where conducted with the transformer components secured together with duct tape, ensuring good alignment. The test were conducted in a high pressure test chamber filled with salt water, and the pressure varied from atmospheric pressure to 3000 psi. Communications and power transfer were tested simultaneously, with power transfer typically at 200 watts. Power transfer efficiency was approximately 83% in the bench tests. No measurable power loss has been detected in the salt water medium as compared operation in to air.

In this same test set-up, data packets were generated on one IBMPC compatible computer and received on a second one. The software used was the "Diagnose" program distributed by SMC corporation with their Ethernet drivers. Transfer was error free through the transfer period of over 12 hours.

As indicated above, to date the only field tests of the power and communications interface has been with the MIT/WHOI Odyssey. Power levels at approximately 200 watts have been demonstrated with efficiencies of about 79%, Bales (1997). In these tests a power conditioner was not used, the rectifier output being directed into a resistive load. The output power tended to

fluctuate as the core alignment changed due to heaving of the mooring, varying from 130 watts to 200 watts.

Data transfer was also demonstrated in these field tests. However, failures of the commercial DC/DC converters used to power the Ethernet prevented the extended use of the communication interface. Because of this, acquisition of communication statistics in the ocean has not been accomplished. Investigation of the preamp failures was not possible, because they were potted on the transformer cores. The Ethernet transmit and receive electronics are now being housed in a separate oil-filled pressure-compensated compartment. This new configuration permits access to the circuit boards and will facilitate investigation of any future failures.

IMPACT/APPLICATIONS

We see two impacts for systems applications. The first in an inductive communication and power link between an underwater vehicle and a dock. This system requires no penetration into the vehicle and has much larger system applications than just the present application. The second is the integrated acoustic/EM homing system. This system is developed to provide the range associated with acoustic systems, combined with near range precision that can only be achieved with the EM system. As indicated, we believe that this is one of the better options for precise homing and positioning. If successfully developed, this system should have applications in underwater homing and positioning systems where precise near range accuracy is required.

TRANSITIONS

The power and communications interface is current being used by the MIT/WHOI AOSN project. It is being used on the AUV developed by Florida Atlantic University.

RELATED PROJECTS:

Most of the applications of the work has been relative to the AOSN project directed by MIT. The progress described in this report has been in close coordination with the Project Director, Jim Bellingham. This project has also worked closely WHOI in testing the interface system. We have also worked with Florida Atlantic University on some of the interface issues.

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